Smart Grid Focused Use Cases for Distribution Grid Management

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1. Problem Formulation

There are many use cases listed and developed in the last five years for the Distribution Grid Management activities. Some of them describe simple operations, like controlling a feeder circuit breaker, other more complex activities performed by an operator via SCADA. These activities are not functions of Distribution Automation. There is a number of use cases developed for DA functions, some of them with participation of Distributed Energy resources, e.g. described in [1]. However, all these use cases do not fully address the Smart Grid requirements. Therefore, tasks 5 and 6 of PAP 8 required development of **Smart Grid focused** master list of critical use cases. The Smart Grid focused use cases should describe functions involving "*digital information and controls technology to improve reliability, security, and efficiency of the electric grid and dynamic optimization of grid operations and resources, with full cyber- security*" [2], including all the Smart Grid technologies (AMI, DER including electric storage, Demand Response, PEV, two-way communications, etc.). The Smart Grid focused use cases will include all the needed steps previously described or suggested in the more simple use cases. Some of the previously developed use cases include Smart Grid focused components. These use cases need to be upgraded to fully meet the Smart Grid requirements [3].

However, there are use cases that need to be developed from start. Among those use cases are use cases that require functional integration and coordination of distribution and transmission operations. The near-real time (dynamic) optimization of the transmission operations will result in fuller utilization of the existing operational tolerances, some of which are critical to the distribution operations. Also, such a significant component of the transmission operation as bus load will become much more dynamic due to the active role of distribution systems and will also become a controllable variable due to the much greater controllability of customer loads and distributed resources. The Load Forecast, Resource Optimization and Planning, Network Monitoring and Optimization functions will require additional near real time and look-ahead information from the distribution systems. On the other hand, information regarding transmission and generation constraints and operational needs will be needed by the distribution systems to optimize its operations within dynamic operational tolerances.

According to the Smart Grid concept, the distribution systems will transform from predominantly no-power-source into an active provider of capacity and energy resources via Distributed Generation, Electric Storage, Demand Response, and PEV. Even now the distribution system is a significant resource of the reactive power. All these above mentioned resources are much more dynamic in distribution systems than the bulk generation. Therefore, one of the critical requirements of the Smart Grid - "dynamic optimization of grid operations and resources, with full cyber- security" cannot be met without integrating the dynamic model of distribution operations into the overall optimization of power supply and delivery. That is why the Report to NIST on the Smart Grid Interoperability Standards Roadmap states that "*it becomes increasingly critical for transmission and distribution operations to have clear and accurate information about the status and situations of each other, they need to be able to exchange their respective T&D power system models including the merging of relevant databases for interconnected power systems*". It does not mean that the background databases used for transmission and distribution operations should be integrated per se. The transmission EMS is not going to expand it basic database and models to cover all the details of the distribution system and vice versa. The respective transmission and distribution models to be exchanged should be based on pre-processed, aggregated information needed by the counterparts from each other.

2. Functions Suggested for Development of Use Cases for DGMI

The development of the use cases should include the following actions:

a. Identify actors
b. Identify interfaces between actors
c. Describe the steps of the function
d. Identify the following functional and communication requirements for information exchange for each step and interface, including interfaces between new applications and legacy systems.
    i. Define the contents of data
    ii. Define the accuracy of data
    iii. Define the volume of data
    iv. Define the time requirements
    v. Define the time synchronization requirements
    vi. Define the storage requirements
    vii. Define security requirements
    viii. Other
e. Define requirements for storing and retrieving integrated data (System configuration and IED data should be retrievable for a given time stamp with the corresponding IED settings, if necessary from different databases)
f. Develop object/data models for each actor and sub-sets of models for each interface.

The following is a non-exhaustive list of functions suggested for development of Smart Grid focused use cases relevant to the Distribution Grid Management Initiative (DGMI).

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Application/Function/Use Case	Domain	Status	Business and Architectural Significance
1. Transmission and generation operation functions requiring additional information about current, future, and look-ahead operations of the corresponding distribution systems in the Smart Grid Environment [4]:			
a. Resource planning functions	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes Demand response, DER, Energy efficiency
b. System planning functions	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes Demand response, DER, Energy efficiency
c. Operation Planning functions	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes Demand response, DER, Energy efficiency
i. Outage scheduling	Cross-cutting: Transmission - Distribution	New	Transmission outage scheduling depends on short-term forecasts of transmission nodal load models, which depend on distribution short-term load forecast, which, in turns, depend on distribution connectivity, outage plans, demand

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			response, distributed generation, electric storage statuses and capabilities, and PEV activities. It will need development of short-term forecasted aggregated load model at the buses of the transmission operation model. The outage scheduling in transmission may impact the LMPs, which in turn impacts the price signals for price-depended objects in distribution (DR, DG). It may also change the voltage angles at interconnected bus, thus impacting the ability for paralleling in distribution needed for distribution outage planning. Hence, with significant penetration of DER and DR, there will be strong interrelationships between the transmission and distribution domain requiring cross-cutting interfaces with multiple iterative information exchanges and new behavioral models designed for inter-domain information exchanges.
ii. Day(s)-ahead operation planning	Cross-cutting: Transmission - Distribution	New	Similar to above
iii. Unit Commitment/Hydro-Thermo Scheduling	Cross-cutting: Transmission - Distribution	New	Similar to above
iv. Transaction scheduling	Cross-cutting: Transmission - Distribution	New	Similar to above
d. Load forecasting functions			
v. System load forecast	Cross-cutting:	New	Similar to above

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	Transmission - Distribution		
vi. Bus load forecast	Cross-cutting: Transmission - Distribution	New	Similar to above
e. Near real-time generation monitoring functions		New	
vii. Reserve monitoring	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes DER, DR, Integrated Volt/var/Watt capabilities
viii. Production cost monitoring	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes impacts of DER, DR, Integrated Volt/var/Watt capabilities
ix. Evaluation of re-dispatch cost	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes impacts of DER, DR, Integrated Volt/var/Watt capabilities
f. Near real-time and real-time generation control functions		New	
x. Economic Dispatch	Cross-cutting,	New	Includes DER, DR, Integrated Volt/var/Watt

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	Generation-transmission-market-distribution-customer		capabilities, and short-term bus load forecast, dependent, in turn, on the DER, DR, and VVWO participation
xi. AGC	Cross-cutting, Generation-transmission-distribution-customer	New	Includes DER, DR, Integrated Volt/var/Watt capabilities, and short-term bus load forecast, dependent, in turn, on the DER, DR, and VVWO participation
xii. Ancillary Services	Cross-cutting, Generation-transmission-market-distribution-customer	New	Includes DER, DR, Integrated Volt/var/Watt capabilities, and short-term bus load forecast, dependent, in turn, on the DER, DR, and VVWO participation
g. Near real-time transmission monitoring functions		New	
xiii. Model Update	Transmission-Distribution	New	Includes availability of controllable devices and DA applications
xiv. Bus load modeling	Transmission-Distribution	New	Include aggregated loads and load-to-voltage/frequency dependencies, and load management (DR) capabilities
xv. State estimation	Transmission-Distribution	New	Include aggregated loads and load-to-voltage/frequency dependencies, and load management (DR) capabilities, information confidence factors
xvi. Limit monitoring	Transmission-	New	Includes dynamic limits determined by

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	Distribution		distribution operations
xvii. Network Sensitivity Analysis	Transmission-Distribution	New	Includes reactions of the distribution operations to changes in transmission systems
xviii. Static contingency analysis	Transmission-Distribution	New	Involves bus load models, DER, Micro-grids, Demand Response, and VVWO.
xix. Dynamic security analysis		New	
• Angle stability	Transmission-Distribution	New	Involves bus load models, DER, and Micro-grids reactions to disturbances in transmission
• Short-term voltage stability	Transmission-Distribution	New	Involves bus load models, DER, and Micro-grids reactions to disturbances in transmission
• Frequency stability (Generation-load mismatch)	Transmission-Distribution	New	Involves bus load models, DER, and Micro-grids reactions to disturbances in transmission
• Slowly developing voltage stability	Transmission-Distribution	New	Involves bus load models, DER, and Micro-grids reactions to disturbances in transmission
xx. Intelligent alarm processing	Transmission-Distribution	New	Involves bus load models, DER, and Micro-grids reactions to disturbances in transmission
h. Near-real-time transmission optimization functions		New	
xxi. Optimal power Flow	Generation-Transmission-Distribution-Customer	New	Involves bus load models, DER, Micro-grids, Demand Response, VVWO
xxii. Security Constraint Dispatch	Generation-Transmission-	New	Involves bus load models, DER, Micro-grids, Demand Response, VVWO

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	Distribution-Customer		
i. Near real-time transmission control functions		New	
xxiii. Close-loop OPF	Generation-Transmission-Distribution-Customer	New	Involves bus load models, DER, Micro-grids, Demand Response, VVWO real-time attributes, and higher speed of information exchange
xxiv. Near real time RAS pre-arming and re-coordination functions	Generation-Transmission-Distribution-Customer	New	Involves bus load models, DER, Micro-grids, Demand Response, VVWO real-time attributes and expected reactions to disturbances , and higher speed of information exchange
xxv. Real-time remedial action functions	Generation-Transmission-Distribution-Customer	New	Involves bus load models, DER, Micro-grids, Demand Response, VVWO real-time attributes and expected reactions to disturbances , and ultra-high speed of information exchange
j. After-the fact analyses of transmission operations functions	Generation-Transmission-Distribution-Customer	New	Involves historic data on distribution and customer system operations.
Distribution operation functions requiring additional information about current, future and potential operations of the distribution and corresponding transmission system in the Smart Grid Environment:			
a. Distribution resource planning functions		New	
xxvi. Distributed generation planning/forecast (incl. ES)	Generation, Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid technology

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xxvii. PEV load and location forecast	Generation, Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid technology
xxviii. Demand response planning/forecast	Generation, Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid technology. Installation of Demand Response in voltage critical nodes and/or downstream from load-critical segments of the distribution system and the ability of controlling the Demand Response from the DA applications significantly increases the benefits of DA applications [8, 10]**.**
xxix. Reactive power compensation planning/forecast	Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid technology
xxx. Pricing forecast	Generation, Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid technology
b. Distribution system planning functions		New	
xxxi. Distribution substations and feeder planning	Transmission, Distribution, Customer	New	Should take into account bulk power system planning, distribution needs, customer planning and prediction of implementation of Smart Grid

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			technology
xxxii. Allocation of manual and automated switching devices	Transmission, Distribution, Customer	New	The optimal allocation of switching devices is driven by the dominant objectives of distribution operation. It shall take into account the current and future basic topology of the distribution system and the capabilities of the multi-level feeder reconfiguration by using automated switching devices. It should also take into account the presence of Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids and the need in synchronization of Distributed Energy Resources and Micro-grids with the basic power system.
xxxiii. Allocation of voltage controlling devices (incl. local for specific needs) and allocation and sizing of reactive power sources	Transmission, Distribution, Customer	New	The optimal allocation of var and voltage controlling devices in distribution is driven by the dominant objectives of distribution operation. It shall take into account the current and future basic topology of the distribution system and the capabilities of the multi-level feeder reconfiguration by using automated switching devices. It shall also take into account the available contribution of real and reactive power from Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids, as well the impact of reactive resources in distribution on the transmission operations
xxxiv. Prioritization of SMI	Transmission,	New	The advanced DA applications are constraint by

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Allocation for the benefits of DA	Distribution, Customer		loading and voltage limits. The most restrictive constraints in distribution are the voltage limits at the customer terminals. There are always some customer terminals that experience either the lowest, or the highest voltages. These voltage-critical points are not always stable, they move from one place to another at different times. The distribution operation model used by the DA application is supposed to determine the voltage-critical points. The accuracy of this determination depends on the accuracies of the component models, such as load models, secondary voltage drop model, connectivity model, etc. These models shall be periodically validated. One of the validation methods is comparison of the modeled value with the accurately measured one. It can be done retroactively by using stored data, or it can be done in the near real-time frame. In order to maximize the benefits from the advanced DA functions, the SMI shall be first installed in point of most interest for the model validation purposes. These sites can be determined by defining the most probable critical points
c. Distribution operation planning functions		New	
xxxv. Planned outage management	Transmission, Distribution, Customer	New	Transmission loading capability and phase angles, distribution capability for reconfiguration, weather forecast, and customer

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			participation should be taken into account
xxxvi. Day(s) – ahead planning of use of Demand Response, Distributed Generation, and Electric storage	Market, Generation, Transmission, Distribution, Customer	New	Expected energy cost, transmission loading capability, distribution loading capability, weather forecast, and customer participation in market should be taken into account
xxxvii. Day(s) – ahead planning of feeder configuration (load swapping for LMP minimization, other)	Market, Generation, Transmission, Distribution, Customer	New	Expected energy cost, transmission loading capability, distribution loading capability, weather forecast, and customer participation in market should be taken into account
d. Distribution load forecasting functions		New	
xxxviii. Short-term distribution nodal load forecast	Market, Generation, Transmission, Distribution, Customer	New	Preprocessed AMI data, expected energy cost, transmission loading capability, distribution loading capability, weather forecast, and customer participation in local load balancing and in market should be taken into account
xxxix. Short-term feeder load forecast	Market, Generation, Transmission, Distribution, Customer	New	Based on short-term distribution nodal load forecast
xl. Short-term substation bus load forecast	Market, Generation, Transmission, Distribution, Customer	New	Based on short-term feeder load forecast and feeder configuration (could be defined by expected LMPs)

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e. Near real-time and look-ahead distribution monitoring functions			
xli. Distribution Operation Modeling and Analysis (DOMA)	Generation, Transmission, Distribution, Customer	The basic use case is described in [1]. Needs upgrade for full Smart Grid requirements.	Needs near-real time information from EMS, Market, Distribution SCADA, data from GIS/CIS, should use load models derived based on AMI-supported data, DER, Demand response, and PEV behavioral models [5 - 7]. The application is based on a real-time unbalanced distribution power flow for dynamically changing distribution operating conditions. It analyzes the results of the power flow simulations and provides the operator with the summary of this analysis. It further provides other applications with pseudo-measurements for each distribution system element from within substations down to load centers in the secondaries. The model is kept up-to-date by real-time updates of topology, facilities parameters, load, and relevant components of the transmission system. The Monitoring Distribution Operation with DR, DER, PEV, and ES function runs periodically, by event and on demand. The periodicity of the runs is in the range of 3-15 minutes. The by event runs should start within one minute and be completed in one minute. The function consists of the following sub-functions:
• Modeling			This sub-function provides topology and

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transmission/sub-transmission system immediately adjacent to distribution circuits			electrical characteristics of those substation transformers and transmission/sub-transmission portions of the system, where loading and voltage levels significantly depend on the operating conditions of the particular portion of the distribution system. The model also includes substation transformers and transmission/sub-transmission lines with load and voltage limits that should be respected by the application. The transmission related information exchange is accomplished over the EMS – DMS interface.
• Nodal load modeling (incl. DG, DR, ES, and PEV)			This sub-function provides characteristics of real and reactive load connected to secondary side of distribution transformer or to primary distribution circuit in case of primary meter customers. These characteristics shall be sufficient to estimate kW and kvars at a distribution node at any given time and day and include the load shapes and load-to-voltage sensitivities (for real and reactive power) of various load categories, as well as financial attributes. In real-time mode, the nodal loads are balanced with real-time measurements obtained from corresponding primary circuits. A validity check is applied to real-time measurements. The load model input comes from Distribution SCADA , from CIS and Behavior Databases for DR, PEF, and ES, supported by AMI, customer EMS, and contractual agreements and linked

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			with AM/FM/GIS, as well as from selected Smart Meters, from aggregators, and from weather forecast systems
• Topology modeling and analysis			This sub-function provides a topological model of distribution circuits, starting from the distribution side of the substation transformer and ending at the equivalent load center on the secondary of each distribution transformer. A topological consistency check is performed every time connectivity changes. The model input comes from SCADA/EMS, Distribution SCADA, from field crews, from DISCO operator, from AM/FM/GIS, from outage detections by AMI, WMS, and OMS databases, and engineers.
• Unbalanced power flow/State estimation			The sub-function models the unbalanced power flow including the impact of automatically controlled devices (i.e., LTCs, capacitor controllers, voltage regulators) and Real Time Pricing (RTP), solves radial and meshed networks with multiple supply busses (DER)
• Loading analysis			
• Voltage quality analysis			This sub-function performs the power quality analysis by: 1. Comparing (actual) measured and calculated voltages against the limits 2. Determining the portion of

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			time the voltage or imbalance are outside the limits 3. Determining the amount of energy consumed during various voltage deviations and imbalance 4. Recording the time when voltage violations occur 5. Summarizing and analyzing voltage quality parameters retrieved from AMI devices. The sub-function provides the ability to estimate the expected voltage quality parameters during the planned changes in connectivity and reactive power compensation.
• Loss analysis			This sub-function bases its analysis on technical losses (e.g., I^2R, core, dielectric) calculated for different elements of the distribution system (e.g., per feeder or substation transformer). For the defined area, these losses are accumulated for a given time interval (month, quarter, year, etc.). They are further compared with the difference between the energy input (based on measurements) into the defined area and the total of relevant billed kWh (obtained from CIS and AMI), normalized to the same time interval. The result of the comparison is an estimate of commercial losses (e.g., metering errors and

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			theft).
• Dynamic limit calculations			This sub-function determines the substation bus voltage limit for the current operating conditions, including limits for optimal operations and for acceptable operations.
• Aggregated load-to-voltage dependencies determination			These characteristics include: aggregated at the buses load-to-voltage dependencies, remedial action schemes parameters, DER protection behavior, etc
• Available real- and reactive load management capabilities determination			The sub-function estimates the available dispatchable real and reactive load obtainable via volt/var control, DER, DR, PEV, and ES and load shedding schemes. The sub-function provides aggregated at the transmission buses operational parameters to be used in transmission operation models.
• Short-circuit analysis			This sub-function calculates a bolted three-phase, line-to-line-to-ground and line-to-ground fault currents for each protection zone associated with feeder circuit breakers and field reclosers. The minimum fault current is compared with protection settings while the maximum fault current is compared with interrupting ratings of breakers and reclosers. The contribution of DER should be taken unto account.
xlii. Distribution contingency	Transmission,	The basic use	Based on DOMA and circuit and customer

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analysis	Distribution, Customer	case is described in [1]. Needs upgrade for full Smart Grid requirements.	reliability data, involves DER and Demand Response [8, 9]. This application performs an N-m contingency analysis in the relevant portion of distribution. The function shall run in the following modes: 1. Periodically 2. By event (topology change, load change, availability of control change) 3. Study mode, in which the conditions are defined and the application is started by the user. The application informs the operator on the status of real-time distribution system reliability and should also be used for operation planning. The updates needed to meet the Smart Grid requirements include the following: a. Using the AMI outage detection capabilities for fault location b. Handling of the Distributed Energy Resources, Demand Response, Electric Storage, and Electric Transportation as generation resources available for backup of the load, when needed Using the capability for intentionally creating micro-grids to maximize the amount of energized loads
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f. Near-real time distribution			

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optimizing and controlling functions			
xliii. Fault Location	Distribution, Customer	The basic use case is described in [1]. Needs upgrade for full Smart Grid requirements	Based on fault indications, AMI, Fault predictors, Fault locators, and combination of above.
xliv. Fault isolation and service restoration	Transmission, Distribution, Customer	The basic use case is described in [1]. Needs upgrade for full Smart Grid requirements	Based on Fault Location, involves DER, DR, Micro-grids, VVWO, Distribution SCADA, distributed intelligence schemes [8, 9]. This application shall support three modes of operation: 1. Closed-loop mode, in which the sub-function is initiated by the Fault location sub-function. It generates a switching order (i.e., sequence) for the remotely controlled switching devices to isolate the faulted section, and restore service to the non-faulted sections. The switching order is automatically executed via SCADA. 2. Advisory mode, in which the sub-function is initiated by the Fault location sub-function. It generates a switching order for remotely- and manually-controlled switching devices to isolate the faulted section, and restore service to the non-faulted sections. The switching order is presented to operator for approval and execution.

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			3. Study mode, in which the sub-function is initiated by the user. It analyzes a saved case modified by the user, and generates a switching order under the operating conditions specified by the user. The generated switching orders are based on considering the availability of remotely controlled switching devices, feeder paralleling, creation of islands supported by distributed energy resources, and on cold-load pickup currents. The updates needed to meet the Smart Grid requirements include the following: a. Using the AMI outage detection capabilities for fault location b. Handling of the Distributed Energy Resources, Demand Response, Electric Storage, and Electric Transportation as generation resources available for backup of the load, when needed c. Using the capability for intentionally creating micro-grids to maximize the amount of energized loads
xlv. Feeder reconfiguration	Transmission, Distribution, Customer	The basic use case is described in [1]. Needs	Involves market and transmission data, DER, DR, Micro-grids, VVWO, Distribution SCADA [9]. This application recommends an optimal selection of feeder(s) connectivity for different

Application/Function/Use Case	Domain	Status	Business and Architectural Significance
		upgrade for full Smart Grid requirements	objectives. It supports three modes of operation: 1. Closed-loop mode, in which the application is initiated by the Fault Location, Isolation and Service Restoration application, unable to restore service by simple (one-level) load transfer, to determine a switching order for the remotely controlled switching devices to restore service to the non-faulted sections by using multi-level load transfers. 2. Advisory mode, in which the application is initiated by SCADA alarms triggered by overloads of substation transformer, segments of distribution circuits, or by DOMA detecting an overload, or by operator who would indicate the objective and the reconfiguration area. In this mode, the application recommends a switching order to the operator. 3. Study mode, in which the application is initiated and the conditions are defined by the user. The application performs a multi-level feeder reconfiguration to meet one of the following objectives: a. Optimally restore service to customers utilizing multiple alternative sources. The application meets this objective by operating as part of Fault Location, Isolation and Service Restoration.

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			b. Optimally unload an overloaded segment. This objective is pursued if the application is triggered by the overload alarm from SCADA, or from the Distribution Operation Modeling and Analysis, or from Contingency analysis. These alarms are generated by overloads of substation transformer or segments of distribution circuits, or by operator demand. c. Minimize losses d. Minimize exposure to faults e. Equalize voltages [1, 2, 3, 11, 14, 22]. Additional objective may include: f. Minimize energy cost by swapping loads g. Unload transmission facilities by swapping loads The updates needed to meet the Smart Grid requirements include the following: a. Using MFR for swapping loads to reduce energy cost and assist in congestion management b. Taking into account the Distributed Energy Resources, Demand Response, Electric Storage, and

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			Electric Transportation as generation resources or as dispatchable loads c. Using the capability for intentionally creating micro-grids to accommodate feeder reconfiguration
• For load balancing			
• For loss minimization			
• For voltage balancing			
• For reliability improvement			
• For transmission support and LMP minimization			
• Feeder paralleling for restoration			
xlvi. Voltage, Var, and Watt Optimization (VVWO)	Market, Generation, Transmission, Distribution, Customer	The basic use case (including DER) is described in [1]. Needs upgrade for full Smart Grid	Takes into account real-time prices (LMP), transmission loading and voltage limits, generation capability curves, operating reserve, transmission losses, distribution operation model, AMI-supported object models, DER and Demand Response operations, controls voltage regulators, capacitors, power electronics, DERs, and Demand Response [8, 10]. This application calculates the optimal settings

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		requirements	of voltage controller of LTCs, voltage regulators, Distributed Energy Resources, power electronic devices, capacitor statuses, and demand response means optimizing the operations by either following different objectives at different times, or considering conflicting objectives together in a weighted manner. It shall support three modes of operation: 1. Closed-loop mode, in which the application runs either periodically (e.g., every 15 min) or is triggered by an event (i.e., topology or objective change), based on real-time information. The application's recommendations are executed automatically via SCADA control commands. 2. Study mode, in which the application performs "what-if" studies, and provides recommended actions to the operator. 3. Look-ahead mode, in which conditions expected in the near future can be studied (from 1 hour through 1 week) by the operator. The following objectives, which could be preset for different times of the day and overwritten by operator if need to, are supported by the application: • Minimize kWh consumption at voltages beyond given voltage quality limits (i.e., ensure standard voltages at customer terminals)

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			• Minimize feeder segment(s) overload • Reduce load while respecting given voltage tolerance (normal and emergency) • Conserve energy via voltage reduction • Reduce or eliminate overload in transmission lines • Reduce or eliminate voltage violations on transmission lines • Provide reactive power support for transmission/distribution bus • Provide spinning reserve support • Minimize cost of energy • Provide compatible combinations of above objectives If, during optimization or execution of the solution, the circuit status changes, the application is interrupted and solution is re-optimized. If, during execution, some operations are unsuccessful, solution is re-optimized without involving the malfunctioning devices. If some of the controllable devices are unavailable for remote control, solution does not involve these devices but takes into account their reaction to changes in operating conditions. The application, if so opted, shall also issue

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			operational requirements to Demand Response means, to Electric Storage devices, as well as to Electric Transportation installations in order to optimally achieve its objective. The application shall be able to utilize selected AMI data directly from the Smart Meters, as well as from the typified object models updated by AMI information.
• For voltage quality support			
• For Demand Response			
• For energy conservation			
• For cost of energy reduction			
• For loss reduction			
xlvii. Relay Protection Re-coordination (RPR)	Distribution, Customer	The basic use case is described in [1]. Needs upgrade for full Smart Grid requirements	Includes coordination of feeder protection and re-synchronization with Distributed Energy Resources and with Micro-grids [11]
xlviii. Pre-arming of Remedial Action Schemes (RAS)	Transmission, Distribution,	The basic us case is	This application receives pre-arming signals from an upper level of control and changes the

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	Customer	described in [1]. Needs upgrade for full Smart Grid requirements	settings (tuning parameters) of distribution-side remedial action schemes (RAS), e.g., load-shedding schemes (a component of self-healing grid) or intentional Distributed Energy Resources islanding into micro-grids. The updates needed to meet the Smart Grid requirements include coordinating remedial action schemes with Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids.
xlix. Coordination of Emergency Actions	Transmission, Distribution, Customer	The basic us case is described in [1]. Needs upgrade for full Smart Grid requirements	This application recognizes the emergency situation based on changes of the operating conditions or on reaction of some RAS to operational changes and coordinates the objectives, modes of operation, and constraints of other Advanced Distribution Automation applications. For example, Under-frequency Load Shedding Schemes trigger emergency load reduction mode of volt/var control, or the under-frequency protection of Distributed Energy Resources triggers the pre-armed intentional islanding. These are post-disturbance activities. The updates needed to meet the Smart Grid requirements include coordinating emergency actions between the RAS, DA applications, Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids.

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l. Coordination of Restorative Actions	Transmission, Distribution, Customer	The basic us case is described in [1]. Needs upgrade for full Smart Grid requirements	This application coordinates the restoration of services after the emergency conditions are eliminated. For example, Advanced Distribution Automation System changes the order of feeder re-connection based on current customer priorities or inhibits return to normal voltage until there are disconnected feeders. The updates needed to meet the Smart Grid requirements include coordinating restoration of disconnected loads in distribution with the availabilities provided by the transmission, generation and distribution itself. It applies to the restoration of load changed due to the emergency by RAS, DA applications, Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids.
li. Intelligent Alarm Processing lii.			This application analyzes SCADA and DOMA-generated alarms and other rapid changes of the operational parameters in distribution and transmission and summarizes the multiple alarms into one massage defining the root cause of the alarms. For example, multiple sudden voltage violations along a distribution feeder and overloads of some feeder segments may be caused by a loss of Distributed Energy

Application/Function/Use Case	Domain	Status	Business and Architectural Significance
			Resources excitation, or successful reclosing of a portion of feeder with loss of significant load may be caused by miss-coordination of the recloser settings and a particular fuse protecting a loaded lateral. The updates needed to meet the Smart Grid requirements include recognition of the impacts by RAS, DA applications, Distributed Energy Resources, Demand Response, Electric Storage, Electric Transportation, and micro-grids on the adverse situations.
liii. Processing AMI data for creating and updating the distribution nodal load models		This is a new function.	Distribution automation applications use comprehensive distribution operation models. The most basic models are the connectivity models and the nodal load models. AMI will provide a large amount of information that can be used to create much more adequate models than the currently used “typical models”. These models include real and reactive load models on per customer basis and models of the voltage drop in the secondaries (as long as the exact topology models for the secondaries are unavailable). In order to obtain these models in a representative and timely manner, the data collected by AMI shall be processed to summarize the essential characteristics of the loads and aggregate the load models at the point of connection in the distribution operation model

Application/Function/Use Case	Domain	Status	Business and Architectural Significance
			used by DA applications**.**
g. After-the fact analyzing distribution operations functions	Transmission, Distribution, Customer		
liv. Evaluation of DA application benefits	Transmission, Distribution, Customer	New	This function monitors and analyzes the results of DOMA and prepares summary monthly reports
lv. Analysis of voltage-critical points	Distribution, Customer	New	This function monitors and analyzes the results of DOMA and prepares summary monthly reports
lvi. Storage and Analysis of past performance of distribution operations	Transmission, Distribution, Customer	New	This function monitors and analyzes the results of DOMA, prepares and archives summary reports.

For the first stage of Smart Grid implementation, the following applications can be recommended:

1) Real-time Distribution Operation Model and Analysis (DOMA)
2) Distribution Contingency Analysis (CA)
3) Fault Location, Isolation, and Service Restoration (FLISR and Intelliteam)
4) Voltage, Var and Watt Control (VVWO)
5) Multi-level Feeder Reconfiguration (MFR).

To raise these applications to the level of the Smart Grid challenges, they should be enhanced in two directions:

   a) Integration with the DER, Demand Response, and AMI
   b) Functional integration with EMS applications.

The integration will better utilize the potential of both: the original DA applications and the new advanced technology, providing significant additional benefits.

Implementing these functions to their maximum extent will require optimal allocation and prioritization of controllable equipment in the distribution system (automated switching devices, controllable capacitors, voltage regulators, demand response installations, etc.). These planning activities cannot be accomplished without knowing what is expected from the DA applications, because different stakeholders may have different dominant objectives and other requirements for these applications. Therefore, in the planning environment, the decisions on choosing the DA applications and on selecting of the actuators should be made at the same time.

Meeting these integration requirements will require development of standard object models and interfaces between different sources. Figures 1-3 are sample illustrations reflecting the needs in the object models and interfaces. These illustrations are updated from the previously published ones in [1].

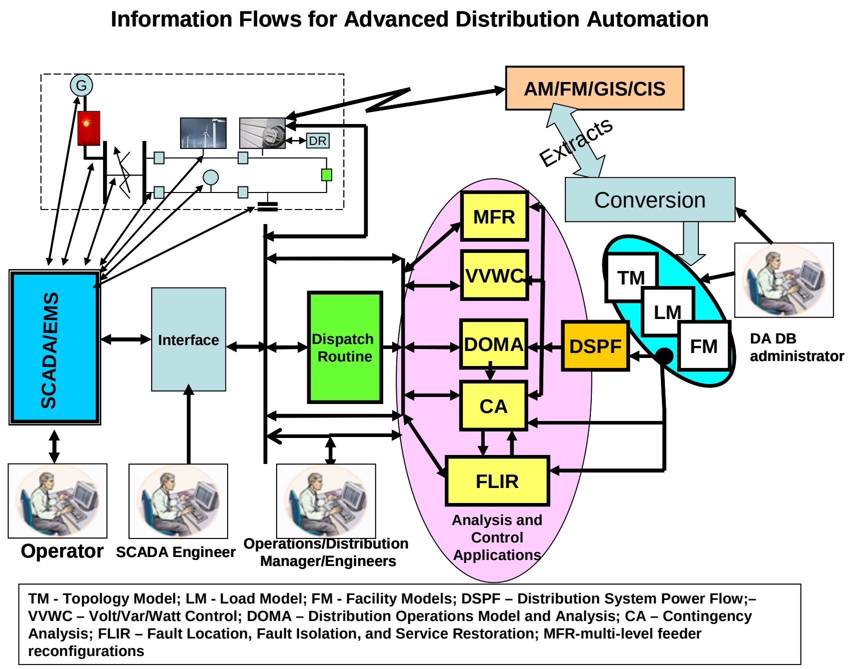

Figure 1. In addition to interfaces with SCADA, specific interfaces between DMS and AMI and DER will be needed

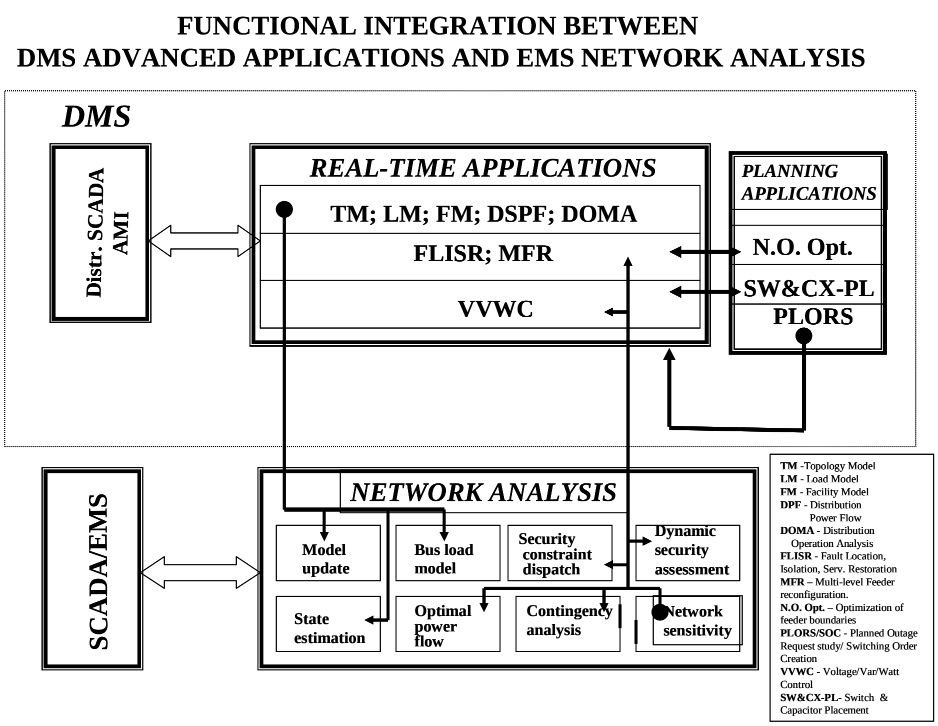

Figure 2. DMS function will provide additional information to the EMS functions, and EMS functions will use additional controllable variables available in distribution

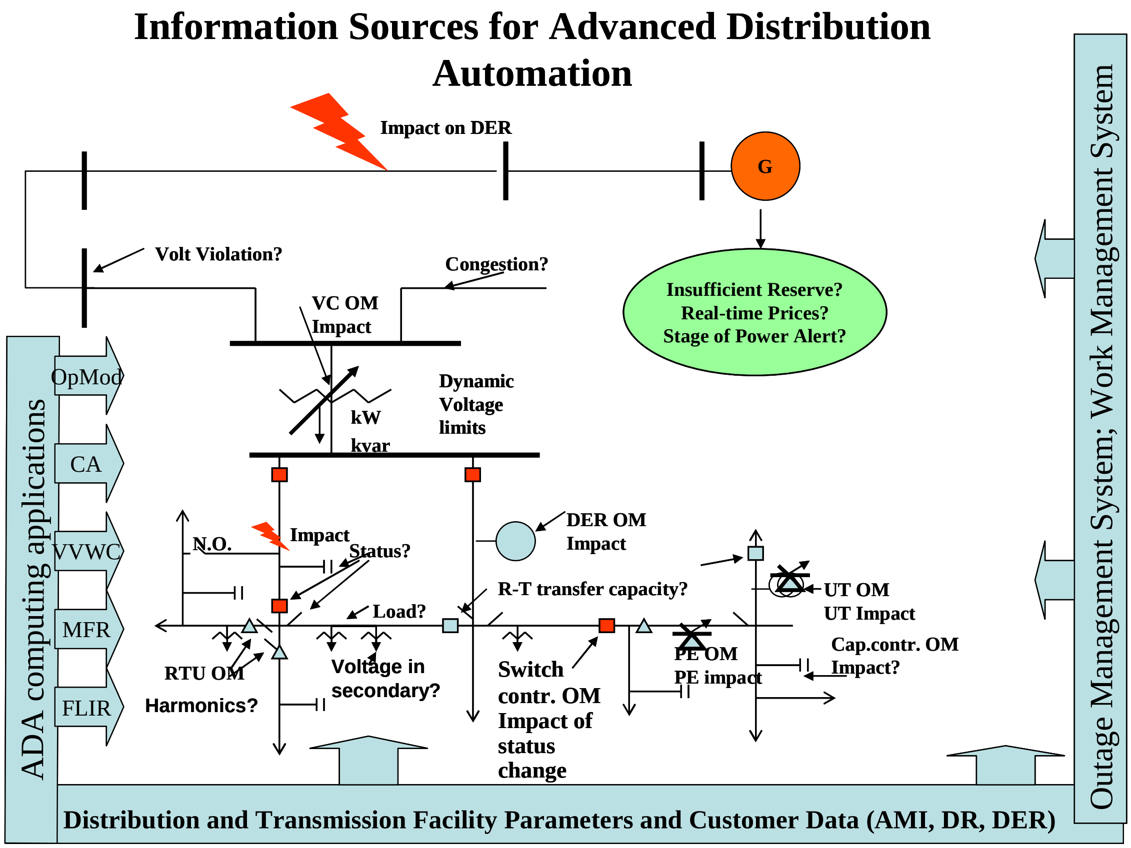

Figure 3. Information resources for DMS with the Smart Grid technology.

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